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Interkosmos laser radar for satellite tracking

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Abstract. This paper describes the technical specifications of the Interkosmos Laser Ranging Radar, pulse processing techniques, system calibration, stability and the effects of various parameters on the accuracy of range mesurements to satellite

A Satellite Tracking and Ranging Station has been established in the campus of Indian Institute of Astrophysics, Kavalur, North Arcot District, Tamilnadu; a joint scientific and technical collaboration between the Indian Space Research Organisation (ISRO) and the Academy of Sciences of USSR (AS-USSR) for the applications in the field of earth and space sciences The satellite tracking station at Kavalur is among the chain of tracking stations belonging to Interkosmos network (IKN). The station is equipped with the sophisticated satellite tracking photographic camera, laser ranging radar, timing equipments and the data reduction equipments.

It is to be mentioned here that the Laser Ranging Radar installed at Kavalur Observatory is not a commercial Laser Radar but it is an outcome of joint efforts of various research institutions and universities of USSR, Czechoslovakia, Poland, Hungary, German Democratic Republic and India.

1. Specifications of interkosmos laser radar

1.1 *Laser Transmitter*

Laser type	Q-switched Ruby Laser (active and passive)
Output Energy	1 joule
Pulse width	15–20 nanoseconds.
Beam divergence	0·5 milli radian at the transmitting telescope.
Pulse repetition rate	1 pulse per second.

1.2 *Laser Receiver*

Receiving telescope	32 cm Cassegrain type.
Focal length	100 cm.
Filter	20 Å narrow band optical filter centered at 694·3 nm.
Detector	RCA 8852
Quantum efficiency	4%
Signal detection level	2 photoelectrons level.

1.3 *Mechanical system*

Laser mount	4-axes system, programmable by mini-computer.
Tracking rate	0·1° per second to 1° per second.
Pointing accuracy to satellite	Better than ±30 arc seconds.

1.4 *Timing equipment*

Timing accuracy (UT)	(i) 25 micro seconds, using Cesium Beam Atomic clock. (ii) ±50 micro seconds, using US-NNSS transit satellites and Doppler receiver. (iii) ±75 micro seconds, using quarts crystal clock and VLF receiver.
Pulse time of flight registration accuracy.	±1 nano second.

1.5 *System performance*

System accuracy	rms error less than 1 meter.
System stability	±2 nano seconds.

In figure 1 is shown the photograph of Interkosmos Laser Radar installed at the tracking station, that is currently in operation.

2. Pulse processing technique

The operation of a Laser Radar for cooperative and non-cooperative objects could be found in standard text books and is not described here (Koechner 1976; Pearlman *et al* 1978). The pulse processing system records the width and area of the outgoing Laser pulses and the pulse shape of the return pulses. The range measurements are referred to pulse centroids to avoid random and systematic errors due to pulse distortions. For this purpose the output from photodetector is fed to the fast integrator with 1 nano second rise time. In the discussion that follows the influence of pulse distortion and the presence of background noise on the range accuracy and system stability are discussed.

3. System calibration

Target calibration is used extensively to measure laser system delay and to verify system stability and performance from time to time. For the purpose of system calibration, a target in the form of a white plano board is fixed at a distance of about 500 meters from the laser ranging unit. This distance is known with an accuracy of ±2 cm from an invariant point on the laser radar. This is the standard reference length respect to which all the range measurements are compared.

Detailed target calibrations over a full dynamic range of the system once in a six months is undertaken to monitor system calibration as a function of signal strength. The operating voltage on PMT is adjusted to avoid saturation and also to ensure that the calibration characteristic remains flat in the range of one to thousand photoelectrons.

An example of a detailed target calibration is shown in figure 2. Each point is averaged approximately of 100 pulses. At low signal strength, the random error due to photon quantisation at the detector dominates over other noise sources in the system and at higher signal level the random error is most likely be due to the jitter in the detector and the long sampling intervals used during calibration (Dixit 1978).

4. System stability and sources of error

In figure 3 is shown the calibration of a laser test target at a fixed photoelectron level for a period of over thirty days. Based on the stability of the pre-calibration and post-calibration differences measured over a period of thirty days, ranging errors introduced in to the data through system calibration are estimated to be about 2 nanoseconds. Extreme care has to be exercised while calibrating laser test target; that is laser is pointing to the target, otherwise the laser pulse reflected from the nearby objects will be modified and will lead to calibration error (Dixit *et al* 1977).

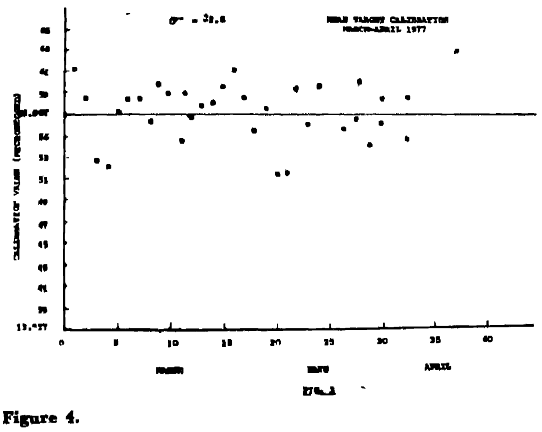

Figure 4.

Range noise in satellite data is a combination of random photon quantisation effects, wavefront distortion, detection system jitter, atmospheric propagation effects and satellite characteristics (Pearlman *et al* 1978).

The return signal strengths from satellites may vary from a few photoelectrons to about thousand photoelectrons during a pass, depending upon the

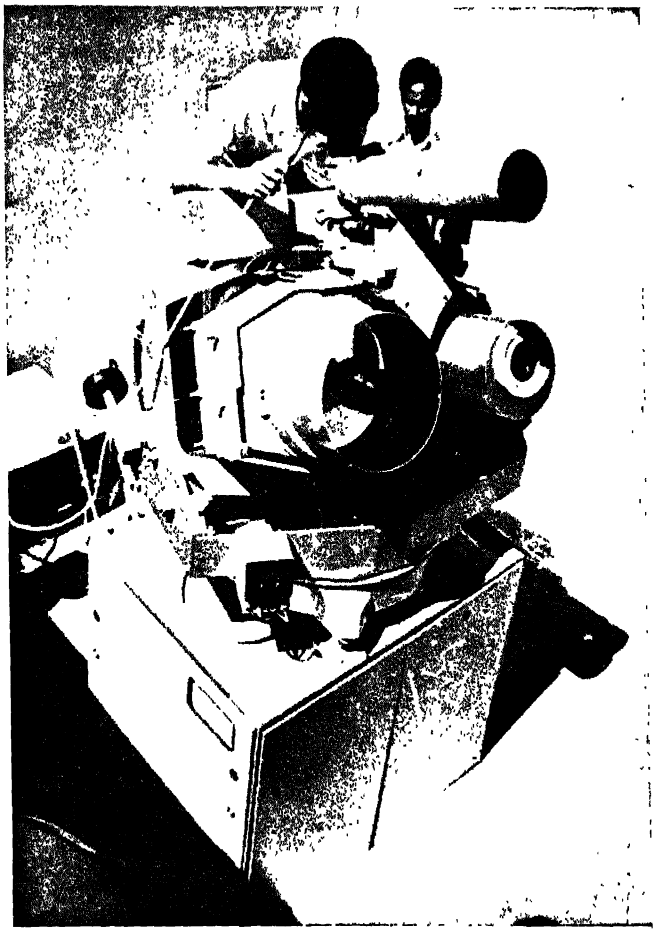

Figure 1. Interkosions Laser Radar

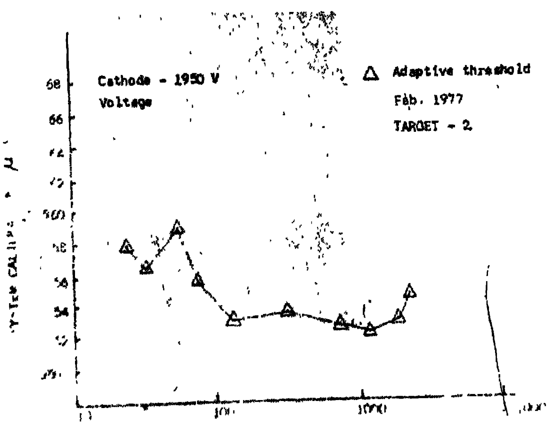

FIG. 1 RETURN SIGNAL STRENGTH (PE)

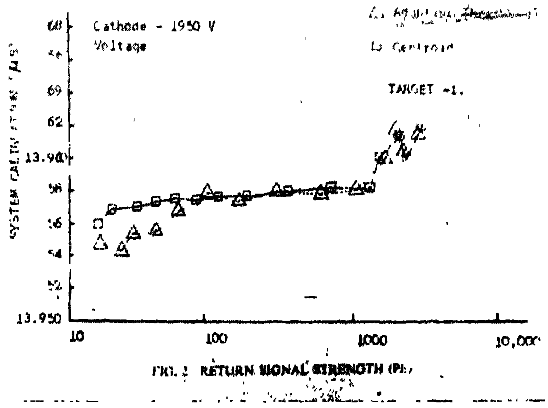

FIG. 2 RETURN SIGNAL STRENGTH (PE)

range of the satellite. In figure 4 is shown the expected signal level from a satellite as a function of range and the area of cross-section of the satellite equipped with retroreflectors. These results are obtained using laser radar equation and the parameters of Interkosmos laser radar described above. In practice, however, one obtains signal level one order below theoretically calculated. This

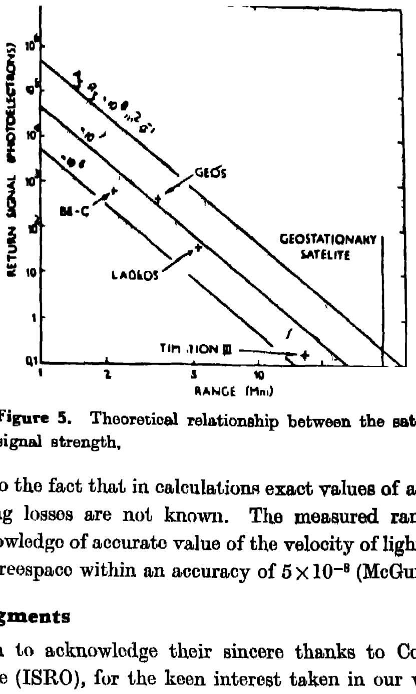

Figure 5. Theoretical relationship between the satellite range and return signal strength.

may be due to the fact that in calculations exact values of atmospheric absorption and scattering losses are not known. The measured range accuracy depends upon the knowledge of accurate value of the velocity of light in atmosphere which is known in freespace within an accuracy of 5×10^{-8} (McGunigal *et al* 1974).

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